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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

00200431.5

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

I.L.C. HATTEN-HECKMAN

DEN HAAG, DEN
THE HAGUE, 29/11/00
LA HAYE, LE

Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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Object positioning method for a lithographic projection apparatus

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"Object positioning method for a lithographic projection apparatus"

The invention relates to a positioning method and a device, in particular for a lithographic projection apparatus. More particular, the invention relates to a method of positioning an object such as a mask or a substrate to a required position on an object table in a lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first object table provided with a mask holder for holding a mask;

a second object table provided with a substrate holder for holding a substrate;

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate.

The term "object" should be interpreted as encompassing both a mask and a substrate. In addition the term "object table" should be interpreted as encompassing both a substrate table and a mask table.

An apparatus of this type can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can then be imaged onto a target area (die) on a substrate (silicon wafer) which has been coated with a layer of photosensitive material (resist). In general, a single wafer will contain a whole network of adjacent dies which are successively irradiated through the reticle, one at a time. In one type of lithographic projection apparatus, each die is irradiated by exposing the entire reticle pattern onto the die in one go; such an apparatus is commonly referred to as a waferstepper. In an alternative apparatus — which is commonly referred to as a step-and-scan apparatus — each die is irradiated by progressively scanning the reticle pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the wafer parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed v at which the wafer table is scanned will be a factor M times that at which the reticle table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO 97/33205, for example.

Up to very recently, apparatus of this type contained a single mask table and a single substrate table. However, machines are now becoming available in which there are at least two independently movable substrate tables; see, for example, the multi-stage apparatus described in International Patent Applications WO 98/28665 and WO 98/40791. The basic operating principle behind such multi-stage apparatus is that, while a first substrate table is underneath the projection system so as to allow exposure of a first substrate located on that table, a second substrate table can run to a loading position, discharge an exposed substrate, pick up a new substrate, perform some initial measurements on the new substrate, and then stand by to transfer this new substrate to the exposure position underneath the projection system as soon as exposure of the first substrate is completed, whence the cycle repeats itself; in this manner, it is possible to achieve a substantially increased machine throughput, which in turn improves the cost of ownership of the machine.

Lithographic apparatus may employ various types of projection radiation, such as ultra-violet light (UV), extreme UV, X-rays, ion beams or electron beams, for example. Depending on the type of radiation used and the particular design requirements of the apparatus, the projection system may be refractive, reflective or catadioptric, for example, and may comprise vitreous components, grazing-incidence mirrors, selective multi-layer coatings, magnetic and/or electrostatic field lenses, *etc*; for simplicity, such components may be loosely referred to in this text, either singly or collectively, as a "lens". The apparatus may comprise components which are operated in vacuum, and are correspondingly vacuum-compatible. As mentioned in the previous paragraph, the apparatus may have more than one substrate table and/or mask table.

In a manufacturing process using a lithographic projection apparatus, a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of energy sensitive material (resist). For this process it is necessary to position the substrate and the mask on respective object tables with a high accuracy, both with regard to each other and with regard to the tables.

If an object, such as a substrate 1 (see figure 2) is not positioned in a correct rotational position on an object table, such as a substrate table, 5 a position measurement error can occur during subsequent alignment of the substrate 1 to the mask. During alignment a substrate 1 is brought into the same rotational orientation as a mask, to which end it can be necessary to rotate the substrate table 5. An interferometer 9 used in a sensor system 7 can be sensitive to this rotation and give an error in the distance which is measured by using a laser beam 11 laterally directed to a side mirror on the table 5. Said error is a so-called *beam-point*

error, which generally increases with increasing rotation of the table 5. The measurement error thus caused can give an error in the super-positioning of two concurrent images exposed on successive layers on the substrate 1. This error in the super-positioning of two concurrent images is generally called an overlay error.

Beam-point errors are caused by inconsistency in the orthogonality of mirror surfaces to interferometer beams. This is illustrated in figure 3a, which shows an interferometer I that measures a distance L between the interferometer I and a mirror T, using a light beam pointed at the mirror T. As here depicted the mirror T has an orthogonality error dS with respect to the nominal incident beam, so that the angle between the beam of incidence and the beam of reflection is 2dS. The total length of the interferometer beam is then B=L+L/(cos 2dS). The distance L can accordingly be calculated from the total length B measured by the interferometer I and from the rotation dS. Optimally, the interferometer beam is directed so as to be parallel to the x-direction in a given reference co-ordinate system. However, factors such as thermal instability and mechanical play can cause a transient deviation from this parallelism, which is referred to as the beam-point error. Figure 3b shows a beam-point error dE at a rotation dS=0. The total length of the beam is B=L/(cos dE) + L/(cos dE). Figure 3c combines the error dE of figure 3b and the rotation dS of figure 3a. The total length of the beam is B=L/(cos dE) + L/cos (dE+2dS). Differentiating this function and applying a small-angle approximation for dE and dS (dE typically being of the order of about 5 to 100μrad), one obtains the expression dB/dE ≈L*dS*dE. From this it is evident that, for relatively high values of dS, the sensitivity of B to beam-point errors increases.

This problem is further deteriorated in that an error in the rotational position of the mirror T (e.g. when mounted on the side of the substrate table 5 in Fig.2) also has an influence on the beam-point error. The influence of this error is twice as big as the beam-point error because, as shown in figure 3a, a mirror rotation has a double influence on the direction of the reflected beam. An error dE_m in the mirror rotation has an influence on the measured total length B of the beam according to the expression $dB/dE_m \approx 2*L*dS*dE_m$. Again, it is evident that, for relatively high values of dS, the sensitivity to errors increases.

Both errors are shown as one-dimensional errors; however in reality these errors are two dimensional, such that the error can be in the plane of figure 3a to 3c (as shown) and also in a direction perpendicular to said plane. Similar considerations apply to the case whereby the object 1 in Fig 2 is a mask, and the object table 5 is a mask table.

Apart from the exposure problems caused by beam-point errors, further problems can arise if the object is wrongly positioned upon the respective object table. Figure 4a shows

a substrate 1 which is correctly positioned upon a vacuum generating surface 13. The substrate 1 covers the vacuum generating surface 13 in total, with only a small overlap between the border 15 of the vacuum generating surface 13 and the edge 2 of the substrate 1. Vacuum from the vacuum source 17 is applied to the vacuum generating surface 13 via the vacuum distribution means 19 and the vacuum chamber 21 to generate a vacuum force F on the substrate 1.

Figure 4b shows a substrate 1 which is incorrectly placed upon a vacuum generating surface 13. The substrate 1 covers the vacuum generating surface 13 in total, but on one side too much overlap occurs between the edge 2 of the substrate 1 and the border 15 of the vacuum generating surface 13. On said one side, less vacuum force F can be applied to the edge 2; consequently, said one side can deform such that it stands up by a small amount. The exposures on said one side can fail because of image deformation on the non-planar edge.

Figure 4c shows a substrate 1 which is also incorrectly placed upon the vacuum generating surface 13. The substrate 1 does not cover the vacuum generating surface 13 in total so that air A will enter the vacuum chamber 21 and the vacuum force F will be less than optimal. During exposure, the badly adhered substrate 1 can move over the vacuum generating surface 13, causing bad exposures to occur. If the substrate 1 gets totally loose, the substrate 1 can fly off the vacuum generating surface 13 and damage the surrounding apparatus.

It is an object of the invention to alleviate, at least partially, the above problems. Accordingly the present invention provides a method of positioning an object to a required position on an object table in a lithographic projection apparatus according to the opening paragraph, characterised in that said method comprises the following steps:

a first placement step in which the object is placed at a first position on the table;

a measuring step in which a displacement between the first position of the object and the required position of the object is determined;

a removing step in which the object is released and removed from the table;

a moving step in which the object and the table are moved relatively to each other by substantially the said displacement, in a direction substantially parallel to the plane of the table; and

a second placement step in which the object is placed at the required position on the table.

The method of the invention enables the positioning of an object, such as a substrate or a mask, with a high accuracy on an object table, such as a substrate table or a mask table, such that when the mask and the substrate are brought into the same rotational orientation during alignment, the required rotation of the table with respect to the employed interferometer system is limited. The increased orthogonality of the object table mirror surfaces to the interferometer beams reduces beam-point errors. Another advantage of the invention is that the object is better positioned upon the vacuum generating surface. Deformation of the edges of the object will be avoided and the exposure of images at the edge of the object will be improved. Also the risks of the object not totally covering the vacuum generating surface is reduced by a better positioning of the object on the table.

The measuring step can be accomplished by aligning a first mark, with a known position on the object, to a second mark. The aligning can be done such that the second mark is located upon the object table (e.g. in the form of a fiducial) upon which the object is placed and has a known position relative to the required position of the object. Another possibility is that the object is located on one object table and that the second mark is located upon the other object table. The aligning can also be done such that the first mark is on the substrate and the second mark is on the mask, or the other way around. Advantageously a plurality of first marks upon the object can be aligned to a plurality of second marks. The measuring step also can be accomplished using imaging means to obtain information about the first position of the object on the table. Said imaging means can be a camera system or a CCD array, able to measure the first position of the object on the table with the required precision. The information thus obtained about the first position of the object on the table, together with information regarding the required position of the object on the table, can be processed in calculating means so as to calculate the said displacement. Said required position of the object on the table can be determined beforehand and stored in a memory device, wherefrom it can be retrieved when necessary. The said displacement can be linear in the plane of the vacuum generating surface of the table and/or can be angular around an axis perpendicular to said surface. The object can be placed on the object table with the aid of vacuum clamping means on a handler arm, for example.

The invention also relates to a device manufacturing method comprising the steps of:

(a) providing a first object table with a first object which contains a pattern;

(b) providing a second object table with a second object which is at least partially covered by a layer of radiation-sensitive material; and

(c) using a projection beam of radiation to project an image of at least a part of the pattern onto a target area of the layer of radiation-sensitive material, characterised in that, prior to step (c), the following actions are performed:

a first placement step in which one of the objects is placed at a first position on its respective object table;

a measuring step in which a displacement between the first position of the said one object and the required position of that object is determined;

a removing step in which the said one object is released and removed from the said respective table;

a moving step in which the said one object and the said respective table are moved relatively to each other by substantially the said displacement, in a direction substantially parallel to the plane of the said respective table; and

a second placement step in which the said one object is placed at the required position on the said respective table.

In a manufacturing process using a lithographic projection apparatus according to the invention, a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of energy-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, *e.g.* an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, *etc.*, all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, *etc.* Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference has been made hereabove to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, *etc*. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target area", respectively.

The invention and its advantages will be further elucidated with the aid of exemplary embodiments and the accompanying schematic drawings, whereby:

Figure 1 schematically depicts a lithographic projection apparatus according to the invention;

Figure 2 explains the effect of a rotational error in the positioning of an object on an object table, on the rotational orientation of the object table.

Figures 3a to 3c explain the occurrence of beam point errors caused by rotating a table relative to an interferometer beam.

Figure 4a to 4c schematically depicts differently positioned objects on object tables.

Figure 5 shows a preferred embodiment of an object table according to the invention.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus according to the invention. The apparatus comprises:

- a radiation system LA, Ex, IN, CO for supplying a projection beam PB of radiation, such as ultraviolet light (e.g. at a wavelength of 365 nm, 248 nm, 193 nm or 157 nm), EUV, X-rays, electrons or ions;
- a first object table (mask table) MT provided with a mask holder for holding a mask MA (*e.g.* a reticle);

- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (*e.g.* a resist-coated silicon wafer);
- a projection system PL (*e.g.* a lens or catadioptric system, a mirror group or an array of field deflectors) for imaging an irradiated portion of the mask MA onto a target portion C (die) of the substrate W.

As here depicted, the apparatus comprises refractive components. However, it may alternatively comprise one or more reflective components.

The radiation system comprises a source LA (*e.g.* a Hg lamp or excimer laser, a thermionic gun or ion source, or a wiggler/undulator situated around the path of an electron beam in a storage ring or synchrotron) which produces a beam of radiation. This beam is passed along various optical components, — *e.g.* beam shaping optics Ex, an integrator IN and a condensor CO — so that the resultant beam PB has a desired shape and intensity distribution in its cross-section.

The beam PB subsequently intercepts the mask MA which is held in the mask holder on the mask table MT. Having passed through the mask MA, the beam PB passes through the projection system PL, which focuses the beam PB onto a target area C of the substrate W. With the aid of the interferometric displacement and measuring means IF, the substrate table WT can be moved accurately, *e.g.* so as to position different target areas C in the path of the beam PB. Similarly, the mask table MT can be positioned very accurately with respect to the beam PB. In general, movement of the object tables MT, WT will be realised with the aid of a long stroke module (course positioning) and a short stroke module (fine positioning), which are not explicitly depicted in Figure 1.

The depicted apparatus can be used in two different modes:

- In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (*i.e.* a single "flash") onto a target area C. The substrate table WT is then shifted in the X and/or Y directions so that a different target area C can be irradiated by the (stationary) beam PB;
- In scan mode, essentially the same scenario applies, except that a given target area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the X direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the projection system PL (typically, M = 1/4 or 1/5). In

this manner, a relatively large target area C can be exposed, without having to compromise on resolution.

Figure 5 shows a preferred embodiment of an object table according to the invention. From the figure the following items can be seen;

- a substrate (wafer) 1 having an edge 2;
- a substrate table 5 comprising a vacuum chamber 21 connected via vacuum apertures 24 to a vacuum generating surface 13 having a border 15;
- a handler 25 comprising an actuator 27, hollow tubes 29 and vacuum clamping means 31 for placing, holding and picking up the substrate 1, said handler 25 being movable through table apertures 30;
- a vacuum source 17 and vacuum distribution means 19 for applying a vacuum to the handler 25 or the vacuum chamber 21 via flexible vacuum tubes 20;
- a table actuator 33 connected to a base frame 35, for moving the table 5;

In a first placement step, the substrate 1 will be placed on the vacuum clamping means 31 of the handler 25 by substrate transporting means (not shown). A vacuum is applied to the vacuum clamping means 31 by opening a valve within the vacuum distribution means 19, which connect the vacuum source 17 to the vacuum clamping means 31 via the hollow tubes 29 and the flexible vacuum tube 20. The vacuum sucks the substrate 1 to the vacuum clamping means 31, whence the substrate transporting means are released and retracted from the substrate 1. The actuator 27 lowers the handler 25 and the substrate 1 to the vacuum generating surface 13 and a vacuum is applied to said surface via the vacuum apertures 24 and the vacuum chamber 21 by opening a valve within the vacuum distribution means 19. This vacuum will apply a vacuum force to the substrate 1 which fixes the substrate to the vacuum generating surface 13 on the substrate table 5. The vacuum on the vacuum clamping means 31 is released (the pressure is raised to the pressure of the environment of the table) within the vacuum distribution means 19 and the handler 25 is further lowered by the actuator 27. The handler 25 can be moved totally out of the table 5 or the handler 25 can be moved a little down and stay inside the table 5.

After this first placement step a measurement step will follow. In that step the position of the substrate 1 on the table 5 will be measured, and a displacement between this first position of the substrate and a required position of the substrate 1 on the table 5 will be determined. This can be done with an off-axis alignment unit (more information with regard to off-axis alignment can be gleaned from International Patent Application WO 98/39689, for example) which measures the position of one or more marks on the substrate 1 relative to one

or more reference marks on the table 5. This will provide very precise information about the first position of the substrate 1 on the table 5, whence a calculation unit (not shown) can calculate a displacement between said first position of the substrate 1 and the required position of the substrate 1. The required position of the substrate on the table can be calibrated beforehand and stored in a memory device. In this required position the interferometer beams will be pointing orthogonal to a mirror (not shown) mounted on the side of the substrate table 5, and the substrate 1 will be positioned correctly upon a vacuum generating surface of the substate table 5. Another possibility is that one or more marks on the substrate 1 be aligned to one or more marks on a mask. During this procedure, also called on-axis alignment, (see for more information with regard to on-axis alignment US 4,778,275, for example) it may be necessary to rotate a table holding the mask and / or to rotate the substrate table 5 to bring the mask and the substrate into the same rotational orientation. Interferometers measure this rotation very accurately and provide the calculation unit with information about the position of the substrate with regard to the mask, whence a displacement between the first position and the required position can be determined. With an on-axis alignment procedure it is also possible to align the marks on the substrate to marks on the mask table and to align marks on the mask to marks located upon the substrate table. Alternatively, imaging means such as a camera can be used to deliver information of the first position of the substrate on the table to the calculation unit.

After this measurement step a removing step can be applied to release and remove the substrate 1 from the substrate table 5. The handler 25 which will be lifted by the actuator 27 such that the vacuum clamping means 31 touch the substrate 1, will accomplish this. After this, a vacuum from the vacuum source 17 will be applied to the vacuum clamping means 31 via the flexible vacuum tube 20 and the hollow tubes 29 by opening a valve within the vacuum distribution means 19. Then the vacuum on the vacuum generating surface 13 will be released by releasing the vacuum within the vacuum distribution means 19, and the actuator 27 will lift the handler 25 and the substrate 1.

After this removing step the table 5 will be moved by the calculated displacement while the substrate 1 supported by the handler 25 stays at the same position. It is also possible that the table 5 be kept still and that the handler 25 be moved by the calculated displacement. Alternatively, both the table 5 and the handler 25 will be moved to achieve the same calculated displacement relative to each other. In general, a pre-alignment unit will be used to ensure a good coarse placement of the substrate 1 on the table 5; in that way, one avoids the need to use a large displacement in the moving step and the table apertures 30 in which the

handler will move through the table can therefore be kept rather small. See for more information with regard to a pre-alignment unit US Patent no. US 5.026,166, for example.

After this moving step a second placement step will be used to place the substrate 1 on the table 5 again. This is done in the same manner as for the first placement step. The substrate 1, sucked to the vacuum generating surface 13 on the table 5, is now in the required position.

By a "vacuum" a reduced gas pressure is of course meant, such as $5.5 * 10^4$ Pa for example, such that the excess external pressure provides a normal force holding the substrate 1 and the vacuum generating surface 13 or the vacuum clamping means 31 against each other. Relative motion between the substrate and the table in the plane of the vacuum generating surface is impeded by the friction between the two components, which is increased by the normal force. The coefficient of friction between the substrate and the vacuum generating surface can, of course, be selected by the choice of material for the contact surfaces.

The above described and illustrated features of embodiments of the invention can be used separately or in any combination. The figures are merely schematic and are not to scale, and the relative dimensions of elements in each figure are not necessarily to scale with each other.

Whilst specific embodiments have been described above, it will be appreciated that the invention may be practised otherwise than as described. For example, if the object is a mask and the invention is used to position the mask on a mask table, the method can be exactly the same, except that the handler for said mask will preferably support the mask at it sides to avoid any damage to the mask.

CLAIMS:

1. A method of positioning an object at a required position on an object table in a lithographic projection apparatus, comprising:

a radiation system for supplying a projection beam of radiation;

a first object table provided with a mask holder for holding a mask;

a second object table provided with a substrate holder for holding a substrate; and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate, characterised in that said method comprises the following steps:

a first placement step in which the object is placed at a first position on the table;

a measuring step in which a displacement between the first position of the object and the required position of the object is determined;

a removing step in which the object is released and removed from the table;

a moving step in which the object and the table are moved relatively to each other by substantially the said displacement, in a direction substantially parallel to the plane of the table; and

a second placement step in which the object is placed at the required position on the table.

2. A method according to claim 1, wherein said measuring step comprises aligning a first mark on the object to a second, reference mark.

3. A method according to claim 2, wherein said second mark is located on the first or the second object table.

4. A method according to claim 2, wherein said second mark is located on the mask or the substrate.

5. A method according to claim 1, wherein said measuring step is accomplished using imaging means to determine the displacement between the first position of the object and the required position of the object.

6. A method according to claim 1, wherein said measuring step comprises processing information about the first position of the object, together with information

regarding the required position of the object, in calculation means, to determine said displacement.

7. A method according to claim 1, wherein said displacement deviation is rotational around an axis perpendicular to the plane of the table.

8. A method according to claim 1, wherein said object is held in place using a vacuum generating surface.

9. A device manufacturing method comprising the steps of:

(a) providing a first object table with a first object which contains a pattern;

(b) providing a second object table with a second object which is at least partially covered by a layer of radiation-sensitive material; and

(c) using a projection beam of radiation to project an image of at least a part of the pattern onto a target area of the layer of radiation-sensitive material, characterised in that, prior to step (c), the following actions are performed:

a first placement step in which one of the objects is placed at a first position on its respective object table;

a measuring step in which a displacement between the first position of the said one object and the required position of that object is determined;

a removing step in which the said one object is released and removed from the said respective table;

a moving step in which the said one object and the said respective table are moved relatively to each other by substantially the said displacement, in a direction substantially parallel to the plane of the said respective table; and

a second placement step in which the said one object is placed at the required position on the said respective table.

10. A device manufactured in accordance with a method according to claim 9.

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ABSTRACT:

"Object positioning method for a lithographic projection apparatus"

A method for placement of a object 1 such as a substrate or a mask on a table 5, said method comprises the following steps:

a first placement step in which the object 1 is placed on a first position on the table 5;

a measuring step in which a displacement between the first position of the object 1 and the required position of the object 1 is determined;

a removing step in which the object 1 is released and removed from the table 5;

a moving step in which the object 1 and the table 5 are moved relatively to each other by substantially the said displacement, in a direction substantially parallel to the surface 13 of the table 5; and

a second placement step in which the object 1 is placed at the required position on the table 5.

Fig. 5

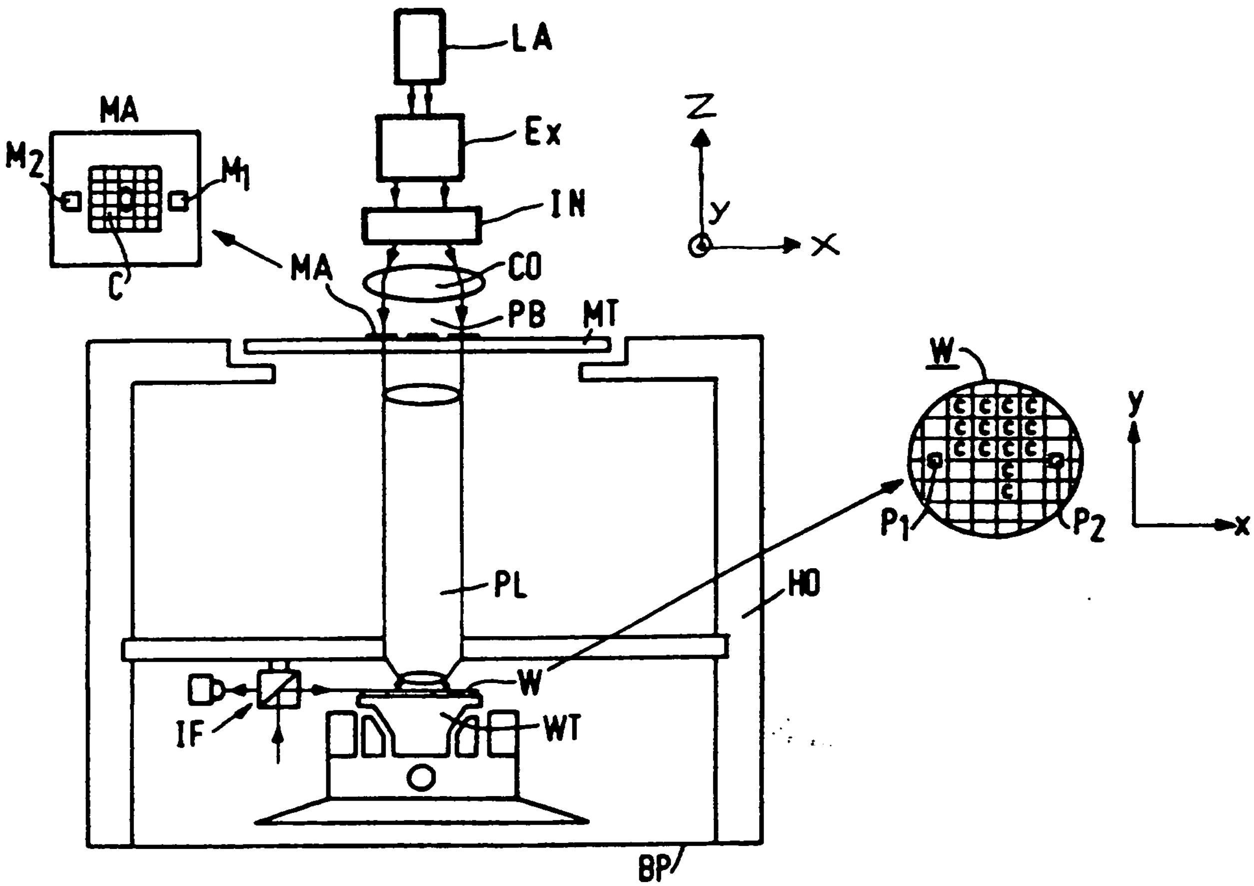


FIG.1

Fig. 2

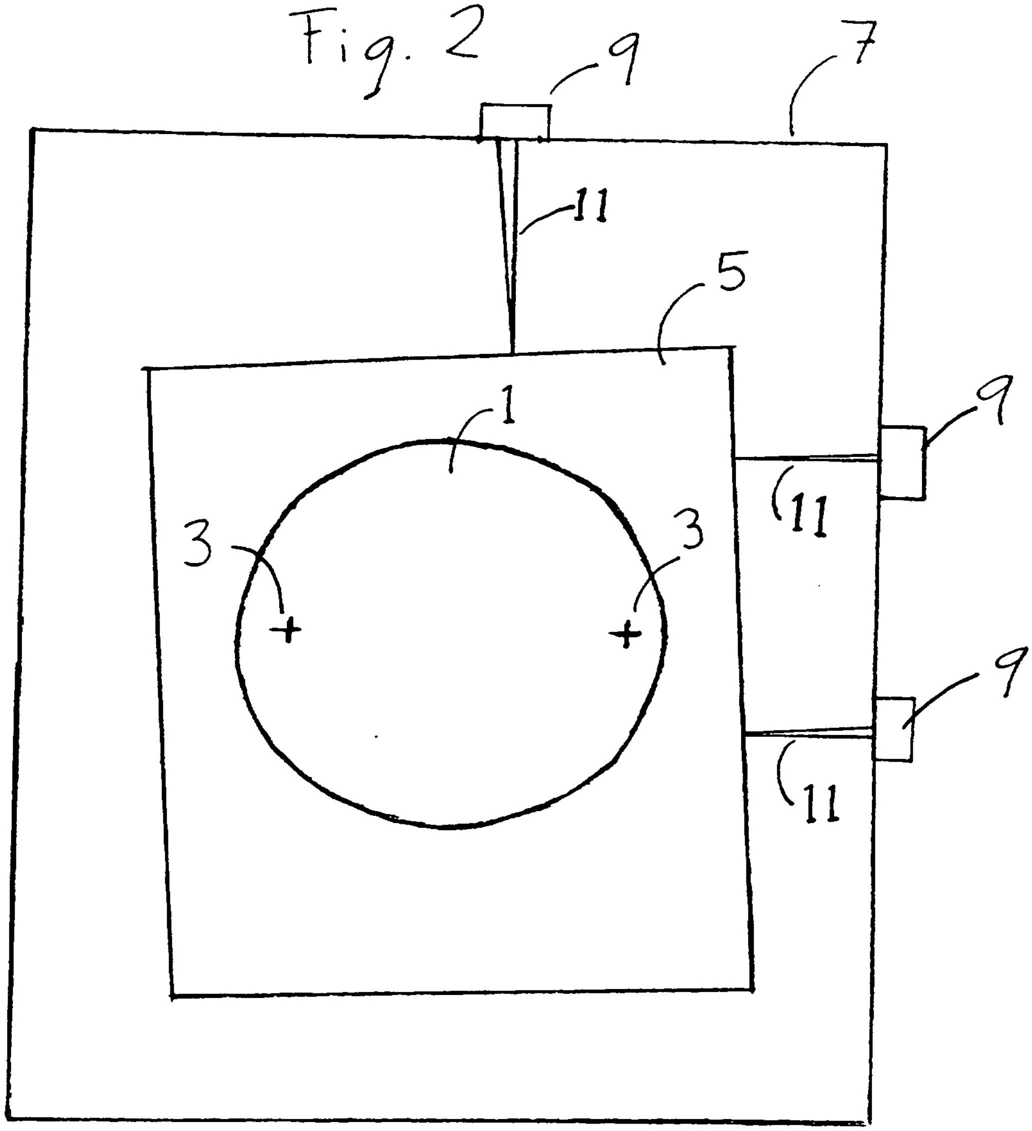


Fig. 3a

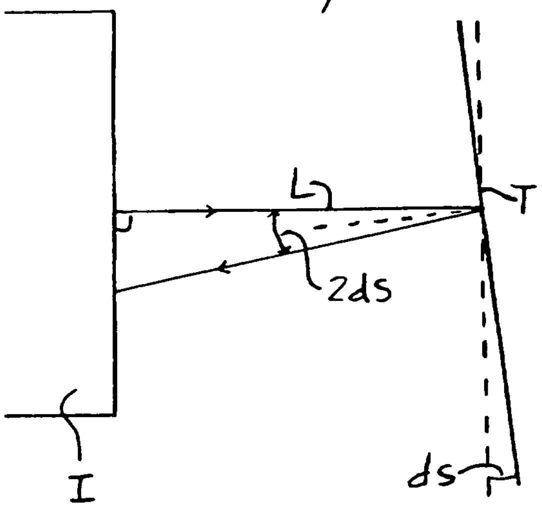


Fig. 3b

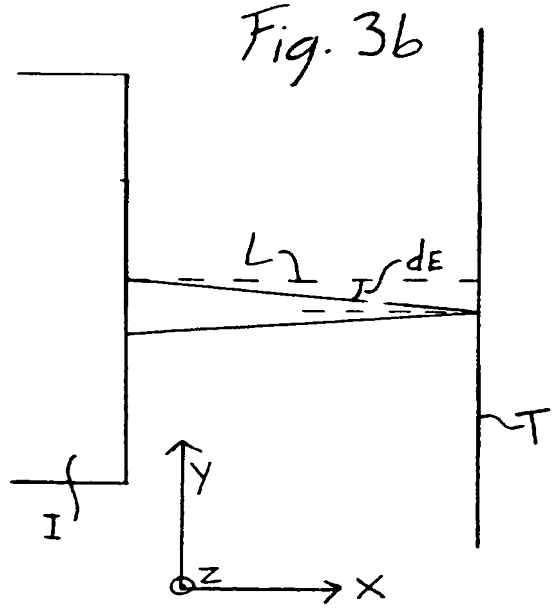


Fig. 3c

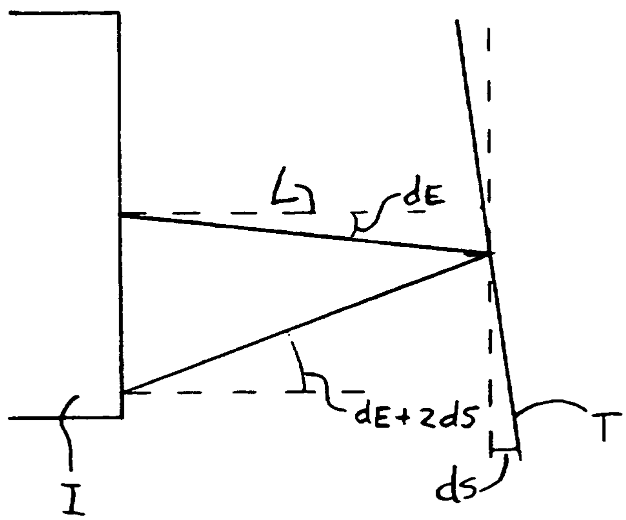


Fig. 4a

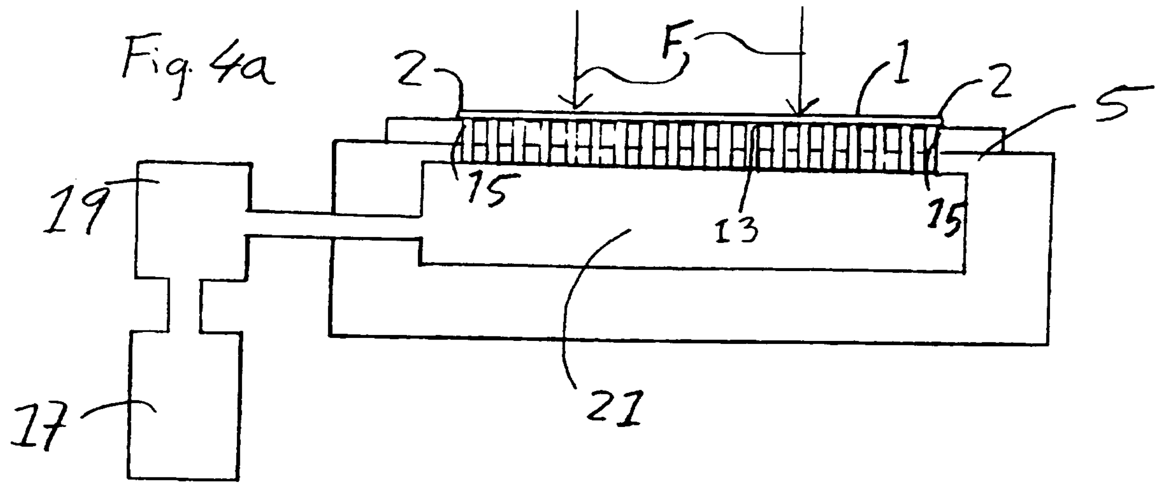


Fig. 4b

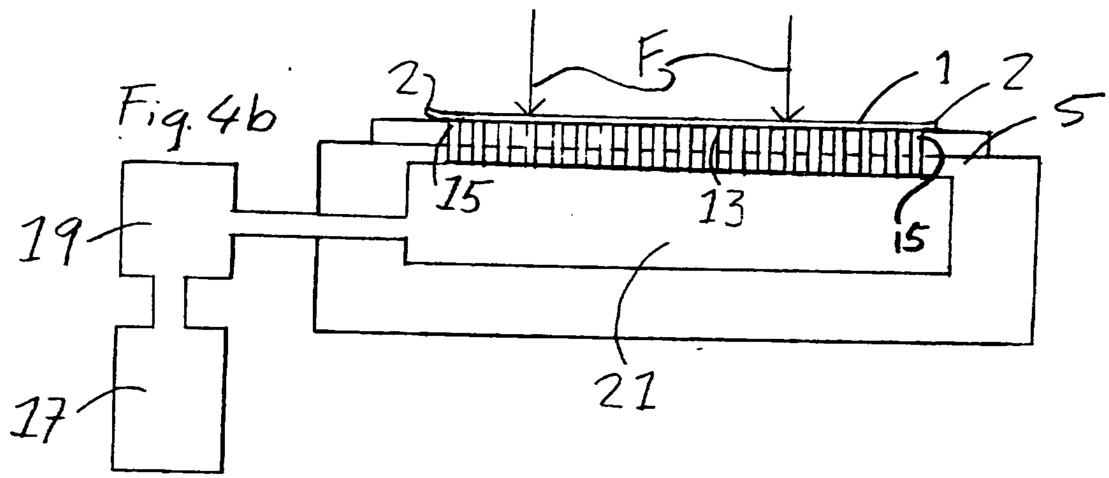
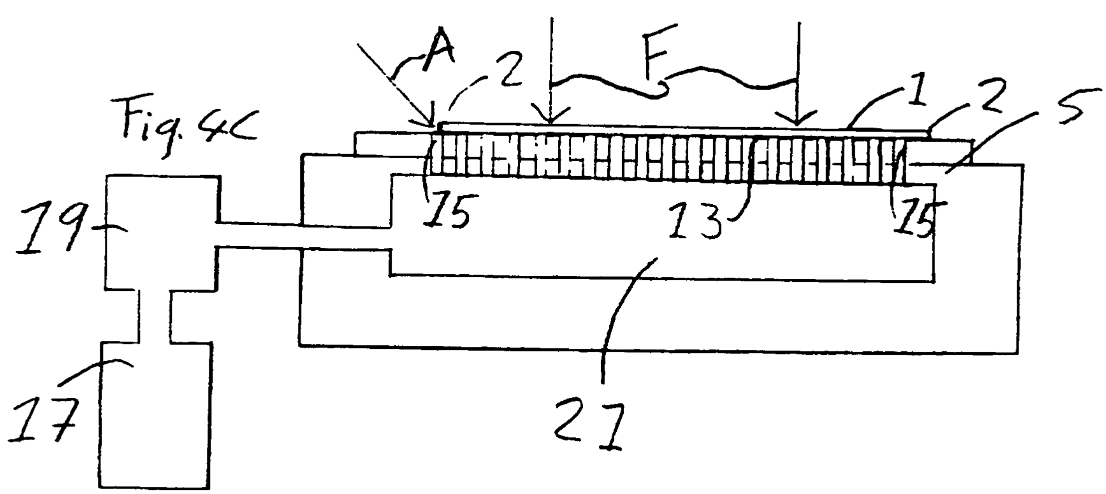


Fig. 4c



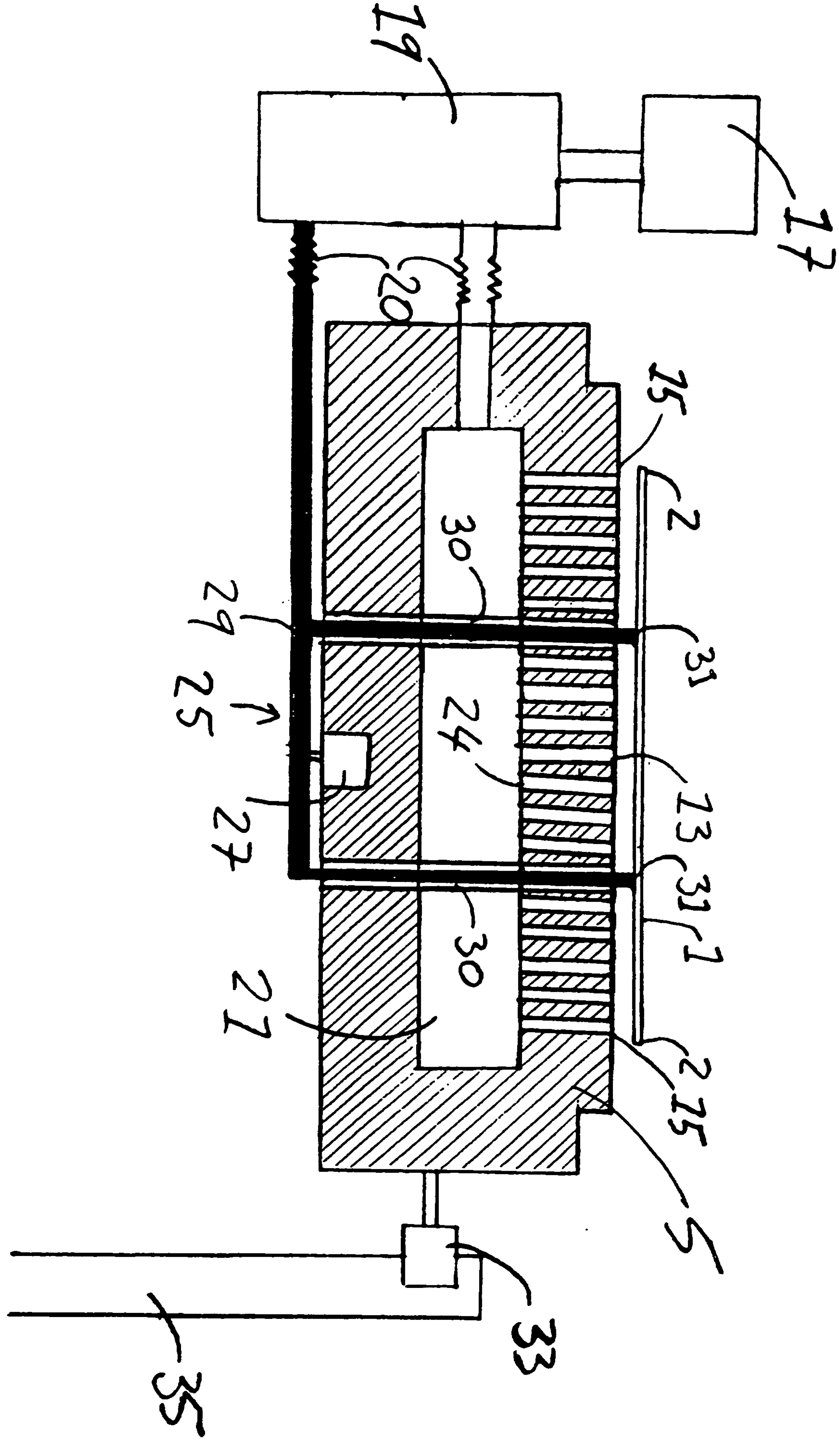


Fig. 5